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No. 1435

STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE
CYLINDERS WITH CUTOUTS

V - CALCULATION OF THE STRESSES IN CYLINDERS

WITH SIDE CUTOUT

By N. J. Hoff and Bertram Klein

Polytechnic Institute of Brooklyn



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V - CALCULATION OF THE STRESSES IN CYLINDERS

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SUMMARY

Stresses were calculated by a numerical method in three reinforced monocoque cylinders subjected to pure bending. The cylinders were of circular cross section and were reinforced with 8 rings and either 8 or 16 stringers. There was a cutout on one side of each cylinder located symmetrically to the neutral plane and extending over 45°, 90°, or 135°. Satisfactory agreement was found between stresses calculated and those measured in part IV in the present series of investigations.

INTRODUCTION

In analytical investigations the reinforced monocoque cylinder is almost invariably assumed to be of constant section and reinforced with evenly spaced stringers and rings of constant cross-sectional properties. In reality, actual airplane structures often have openings for doors, windows, and so forth, and are reinforced locally near points of application of concentrated loads. It is believed that the stress problem of such nonuniform structures is best approached by numerical methods.

In a series of investigations carried out at the Polytechnic Institute of Brooklyn Aeronautical Laboratories an effort was made to apply Southwell's relaxation method (reference 1) to the calculation of the stresses in reinforced monocoque structures. Procedures were developed for reinforced flat and curved sheets (references 2 and 3) as well as for fuselage frames (references 4 and 5). Finally, numerical methods were used to determine the stresses in a reinforced monocoque cylinder having a symmetric cutout on the compression side (reference 6). The results obtained were in satisfactory agreement with experiments carried out earlier, which are described in reference 7. The present report deals with the problem of the stress distribution in a reinforced monocoque cylinder having a side cutout and subjected to pure bending. The results of the calculations are compared with the experiments described in reference 8.

In the first step of the procedure the structure is divided into elements, and the elastic properties of the elements are determined. In the present problem a sheet panel with its bordering segments of stringers and rings was chosen as the element of the reinforced monocoque cylinder. When the loads are applied to the cylinder, the corners of the panels undergo, in general, displacements in arbitrary directions. For the purposes of this calculation the displacements are resolved into axial (in the direction of the axis of the cylinder), tangential (in the direction of the tangent to the ring), and radial components (in the direction of the radius of the ring). At the same time, the corners are, in general, rotated about axes of arbitrary direction, and this rotation is resolved into rotations about the axial, tangential, and radial directions.

In the so-called unit problem it is assumed that the four corners of the panel are rigidly clamped to some imaginary rigid body to prevent both displacement and rotation. Then the clamps are released at one corner to permit displacement or rotation in one direction only, and a displacement (or rotation) of unit magnitude is undertaken in that particular direction. Next the reaction forces and moments caused by the displacement (or rotation) undertaken are calculated for all the four corners.

After all the unit problems of the structure are solved, the results are combined in what are termed the "operations tables." These tables are a systematic presentation of the reactions at all the corner points corresponding to unit displacements of the corner points. It is then required to find a combination of all the displacement (and rotation) components corresponding to zero resultant force and moment at each corner point at which no external load is applied and to force and moment resultants equal and opposite to the loads at the points of application of the external loads. According to Southwell's suggestion, this combination of displacements is found by systematic step-by-step approximations. At the Polytechnic Institute of Brooklyn Aeronautical Laboratories such solutions by step-by-step approximations have been established for reinforced panel problems (references 2 and 3), but when the same approach was tried for the case of monocoque cylinders having symmetric cut-outs and subjected to pure bending, the number of steps needed became almost prohibitive. On the other hand, the solution by matrix methods of the system of linear equations represented by the operations tables together with the applied loads was possible with a reasonable expenditure of work.

In the present report, the displacements are calculated from the operations tables by means of a slightly modified version of Crout's method of solving matrix equations. (See reference 9.) The number of unknowns is 34, 36, and 30 in the case of the cylinders having 45°, 90°, and 135° cutouts, respectively. The numerical part of the work was carried out on semiautomatic electric calculating machines, and 10 digits were kept throughout the calculations. As an approximate rule, it may

be stated that matrices of the kind encountered in this work can be solved by an experienced calculator at the rate of 2 hours for each unknown quantity. This estimate does not allow for mistakes.

Once the displacements are known, the stresses can be easily calculated with the aid of the solutions of the unit problems and elementary considerations. Complete numerical calculations were carried out for three cylinders of the experimental series described in reference 8. Satisfactory agreement was found between theory and experiment, as may be seen from the comparison shown in the figures of the present report.

The authors acknowledge their indebtedness to Mr. Bruno A. Boley for his help in the theoretical aspects of the problem and to Mr. John G. Pulos, who took part in the calculations. The work was carried out under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

SYMBOLS

a.	distance between adjacent rings
Α.	cross—sectional area of stringer augmented by its effective width of curved sheet
A,B,C,A*,B*,C*	rings of cylinder or quadrants of operations table
E	Young's modulus
G-	shear modulus
L	length of ring segment between adjacent stringers
М	externally applied bending moment acting on cylinder
m	ring influence coefficient
N	bending moment acting in plane of ring
Q	torque acting on rigid end ring
r	radius of monocoque cylinder
m, n	ring influence coefficients
R	radial shear force acting in plane of ring
t	thickness of sheet covering
tt, tr, tn	ring influence coefficients

T	tangential force acting in plane of ring
u	tangential displacement
v	radial displacement .
w	rotation
x	force acting in axial direction
¥	vertical shear force acting on rigid ring
at, ar, an	coefficients used in calculation of forces and moments caused by shear flow existing in panel
$\Gamma = Gt/2$	
η	vertical downward translation of rigid ring
θ	rotation of rigid ring in its own plane
ŧ	axial displacement
ထ	rotation of rigid ring about its horizontal diameter
$\Omega = Gta/4L$	

STATEMENT OF PROBLEM AND ASSUMPTIONS

The three cylinders for which calculations were carried out are shown in figure 1. They are Cylinders 35, 39, and 40 of the present series and are described in reference 8. A number of structural changes were assumed for the purpose of calculations in order to decrease the work required for the solution of the problem.

Figure 2 shows the three cylinders in their modified forms. In reality, Cylinder 35 had 16 stringers, 7 of which were omitted in the simplified setup. The cross-sectional areas of the stringers eliminated, however, were distributed evenly between the adjacent stringers that were left in the structure. Similarly, two rings were omitted from the complete portions of the cylinder and the cross section of one was added to the adjacent ring bordering the cutout and the other to the rigid end ring of the cylinder. At the same time the length of the field extending from the cutout to the end ring was assumed to be 9.6429 inches. This field length is $1\frac{1}{2}$ times the actual ring spacing and thus it is an intermediate value between the true distance from cutout to end ring and the actual ring spacing. It was not considered advisable to use a

field length of three times the ring spacing in the calculations because long fields are weak in shear.

Cylinders 39 and 40 were built with only eight stringers. Consequently, changes in the structural arrangement were assumed only in connection with the rings. The changes were of the same nature as in the case of Cylinder 35.

As in previous work, the bending and torsional rigidities of the stringers were disregarded. The rings were considered resistant to bending in their own plane but weak in bending out of their plane as well as in torsion. The extensional and shearing rigidities of the rings were considered. The sheet panels were assumed to resist shear only, and the shear stresses were assumed to be distributed uniformly. The resistance of the sheet to extension and compression was taken approximately into account by adding an effective width of sheet to the stringers. In the present calculations the total width of the sheet was considered effective, since the stresses were calculated for small loads when the sheet is in a nonbuckled state. An effective width of sheet equal to the width of the ring was added to the ring when its cross-sectional properties were calculated. Because of these assumptions only the three displacement components as well as the rotation component about an axis. parallel to the axis of the cylinder need be taken into consideration. Rotations about the tangential and radial axes are not resisted by either the stringer or the ring.

The vertical plane of a transverse section through the middle of the cylinder was regarded as a fixed reference plane relative to which the rigid end rings are tilted — and even twisted because of the asymmetric cutout — when the pure bending moments are applied to the end rings. The operations tables were set up for only one—quarter of the cylinder because the displacements in the four quarters are related by symmetry.

SETTING UP AND SOLVING THE OPERATIONS TABLES

A schematic arrangement showing the four quadrants of the operations tables for all three cylinders is given in table 1. As a rule, each entry in the operations tables (see, for instance, quadrant A, table 2) represents the magnitude and the sign of the generalized force, indicated at the left end of the row in which it appears, caused by the generalized unit displacement indicated at the top of the column. A generalized displacement is a displacement of the structure at a point in one of the directions of the axes, a rotation about one of these axes, or any combination of displacements and rotations of the structure at a group of points. A generalized force corresponding to a generalized displacement is the quantity — force, moment, or group of forces and moments — that gives the work done during the generalized displacement when multiplied by the generalized displacement. As was mentioned under STATEMENT OF PROBLEM

AND ASSUMPTIONS, the structure is considered to be rigidly clamped as regards every other generalized displacement when the effect of any one generalized unit displacement is sought.

The generalized forces in a reinforced monocoque cylinder caused by generalized unit displacements can be calculated when the solution of the so-called four-panel problem is known. The solution was given in reference 6. It is given in a slightly more convenient form in figures 3 to 6 of the present paper. These figures show the forces and moments at each of the nine corner points that are caused by generalized unit displacements of the middle point. The expressions are given in a form suitable for calculations even when each stringer and ring segment has a different but constant section and each panel a different but constant thickness. When a panel is in a buckled state, a reduced value should be used for its effective shear modulus $G_{\rm eff}$. When a panel is absent, its shear modulus, or thickness, should be put equal to zero. The values of the shear flow-force coefficients $\alpha_{\rm t}$, $\alpha_{\rm r}$, and $\alpha_{\rm n}$, as well as those of the influence coefficients tt, tr, tn, rr, . . . , must be obtained from reference 5.

Figures 7 to 10 give the solution of the four-panel problem for the case in which the curvature is opposite to that shown in the preceding four figures. The calculations with which this report deals indicated the desirability of two such sets of diagrams in order to reduce the likelihood of numerical errors and errors of sign in the operations tables.

Because of the symmetry of both the structure and the loading with respect to the plane of a transverse section through the middle of the cylinder, displacements of corresponding points must be the same on rings A and A*, B and B*, and C and C*. (See fig. 2.) Moreover, the loading is antisymmetric with respect to the horizontal plane containing the axis of the cylinder. Hence, displacements of corresponding points on stringers 1 and 1°, 2 and 2°, and so forth, must be antisymmetric. Their absolute magnitudes are equal and their signs can be determined from the following rules, which take care of the peculiarities of the sign conventions adopted: axial and radial displacements are of opposite sign, tangential displacements and rotations are of the same sign on the upper and lower halves of the cylinder. These symmetry considerations permit a reduction in the number of displacement quantities to be entered in the operations tables. Of the total of $4 \times 48 = 192$ possible generalized basic displacements in the case of Cylinder 39, a total of 108 could be omitted outright: 36 more displacements were considered only indirectly, as is shown by means of the following two typical examples.

When point B^{\downarrow}_{1} — the point of intersection of ring B with stringer $^{\downarrow}_{1}$ — is moved in the positive axial direction, point B^{\downarrow}_{1} must be moved the same distance in the negative axial direction because of the antisymmetry.

This combination of displacements causes twice as much shear strain in the panel bounded by rings A and B and stringers 4 and 4 as would be caused by the displacement of point B4 alone. Consequently, the forces and moments appearing because of the shear at points A4 and B4 will be doubled.

When point B4 is moved in the positive tangential direction, point B4' also must be moved the same distance in the tangential direction. Consequently, the shear strain in the panel bounded by rings A and B and stringers 4 and 4° is again subjected to the double amount of shear strain just as in the case discussed previously. Moreover, segment 4-4: of ring B is rotated but not shortened, whereas in the case of a tangential motion of point B4 alone a shortening also would take place. Consequently, 48 independent displacement quantities remain to be entered in the operations tables. This number is further reduced because of the end conditions. In the experiment the end rings were heavy and were rigidly attached to heavy end plates. For this reason, in the theory the end rings were assumed perfectly rigid and points on the end rings were permitted to participate only in rigid body displacements. Thus $4 \times 4 = 16$ further individual generalized displacements are eliminated; and three rigid-body displacements are introduced - namely, a rotation w about the horizontal diameter, a rotation θ about the axis of the cylinder, and a vertical translation n of the end ring. Hence 35 unknown quantities remain.

When the pure bending moment is applied to the rigid end plate, the distribution of the forces to the stringers is not known. Obviously, it cannot be assumed according to the customary linear law because of the cutout in the structure. For this reason a rotation ω of the end ring was specified rather than a bending moment, and the corresponding bending moment was calculated only after the forces in the stringers were determined from the operations table. Hence, the forces and moments corresponding in the operations tables to the specified rigid body displacement ω were known quantities and had to be considered as the load terms in the equations. They are given in the last column of quadrants B and D of table 2.

It will be noted that the last two rows in the operations tables are denoted (1/2)Y (one-half the vertical shear force acting upon the end ring) and (1/2)(Q/r) (one-half the torque acting upon the end ring divided by the radius). This choice of the quantities to be entered in the last two rows results in a symmetric operations table.

The linear equations represented by the operations tables were then solved by a slightly modified version of Crout's method. In other words, the set of 3^{th} displacement quantities causing forces and moments at all the points equal and opposite to those given in the last column of the operations tables (which are due to the specified rotation ω) was determined. These forces and moments listed in the last column are designated RHS to indicate right—hand—side members. It should be noted that two of the displacement quantities listed are the remaining two

(unknown) rigid body displacements θ and η of the end ring. The generalized force corresponding to θ is a torque, that corresponding to η , a vertical shear force. Obviously, these two generalized displacements must be so chosen as to yield zero generalized forces when the external load applied to the cylinder is a pure bending moment. These two requirements are represented by the last two rows of the operations tables.

Similar considerations can be advanced in the case of the other two cylinders. The operations table of Cylinder 40 having the 135° cutout differs from table 2 only in quadrant D. This quadrant is given in table 3. In the case of Cylinder 35 all four quadrants are different. They are shown in table 4. In quadrant A of table 4 the columns of the tangential displacement and the rotation of point Bl correspond to two units each rather than to one. The doubling of these movements was undertaken in order to maintain the symmetry of the operations tables in spite of the assumptions regarding the simultaneous movements of points on the two sides of the horizontal plane of symmetry of the cylinder.

APPROXIMATE THEORY

Because of the great amount of work required for the solution of stress problems by the numerical method discussed, the possibility of using an approximate theory was investigated. The approximation amounted to neglecting all influences except that of the axial displacements. Physically the structure corresponding to the approximate theory would have rigid rings. Moreover, these rings would have to be supported in their own plane to provide reactions, since the shear forces and the torque acting upon the rings are not canceled in the approximate calculations.

The operations tables of the approximate theory are identical with those portions of the operations tables (tables 2 to 4) that involve only axial forces and displacements.

PRESENTATION AND DISCUSSION OF RESULTS

The displacements calculated for a rotation ω of the end ring amounting to 1×10^{-14} radian are presented in tables 5 to 7. The distortions of the rings corresponding to an applied bending moment of 20,000 inch-pounds are shown in figures 11 to 14.

The axial strains calculated from the displacements are plotted in figures 15 to 20, which also contain experimental results taken from reference 8 as well as calculated values corresponding to the approximate theory. The agreement between theory and experiment is

satisfactory. The approximate theory is also in reasonable agreement with experiment in the complete portions of the cylinders. In the cutout portions the values calculated by the approximate theory are even slightly closer to the experimental points than the values obtained from the complete theory. The displacements calculated by the approximate theory are listed in table 8.

Figures 21 and 22 show the shear stresses in the sheet of the complete portions of the cylinders and the maximum bending stresses in the rings bordering the cutout. The absolute values of these stresses are very small. Moreover, they decrease in an oscillatory manner from the region of the neutral axis of the cylinder on the cutout side toward the neutral-axis location on the opposite side.

The bending moment required to cause a rotation of 1×10^{-1} radian of the rigid end ring with respect to the transverse plane of symmetry is 5075.45, 7845.90, and 4511.04 inch-pounds in the case of the cylinders having 45°, 90°, and 135° cutouts, respectively. It should be remembered that the construction of the cylinder with the 90° cutout was different from that of the other two.

CONCLUSIONS

During the course of the calculation of the stresses in three reinforced monocoque cylinders with side cutout, carried out by means of a numerical procedure developed in part IV in the present series of investigations, the following principal observations were made:

- 1. The problem can be stated mathematically by means of a set of simultaneous linear equations represented by the operations tables and the external loads. The operations tables can be set up without difficulty if use is made of the solutions of the four-panel problem contained in the present report, together with the coefficients presented in the tables and graphs given in NACA TN No. 999.
- 2. The equations can be solved by Crout's method at the rate of approximately 2 hours for each unknown quantity. This estimate does not allow for errors.
- 3. The calculated values of the normal strain in the stringers were in satisfactory agreement with the strains measured in the experiments of part IV of the present series of investigations.
- 4. The shear stress in the sheet and the bending stress in the rings were found to be very small.

5. An approximate method which considers only the axial displacements and thus does not satisfy all the equilibrium conditions gave results reasonably close to those obtained by the complete method.

Polytechnic Institute of Brooklyn Brooklyn N. Y., July 3, 1946

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TABLE 1 - SCHEMATIC ARRANGEMENT SHOWING THE FOUR QUADRANTS OF THE OPERATIONS TABLES FOR ALL THREE CYLINDERS

A	В
C	D

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TABLE 2 - OPERATIONS TABLE FOR CYLINDER 39 WITH 45° CUTOUT.

	E _{C4}	U _{C4}	V _{C4}	W _{C4}	₹84	U _{В4}	V ₈₄	₽ 84	₹ _{c3}	u _{C3}	A ^{C3}	Wa	≒ ₈₃	n ^{B3}	V 53	¥ 53
X _{C4}	1179.6013728	11.577150	5.53227948	1.2284986	354,893956	11,577150	5.53227048	2284980	9,5766229	11.577 5]. 84.499315	77.84985	9,5700229	11.57755	1.84409315	1,2284986
T _{C4}	1).577150	43.7/25289	1.5108042	5.30127106	11,577150	41.906748	2,2793 85	4,455384	11,577/5	12.2824313	1.5108042	0.5133867	11.57715	13.995583	2.2293185	1.485128
R _{C4}	5.53227948	1.5108042	1.41480662	0.0769458	5.5327/948	2.2793185	1.065307/4	0. 23856 21	.84409316	1,5[08042	0.07897268	0,9769458	1.04409316	2, 229318 5	0.35510238	0.2305021
N _{C4}	1.2284986	5,30 27 05	0.0769458	2.0392002	1,2284986	4,455384	0.2365621	0.477.7787	1.2284986	0.5133567	0.0769458	0.1499924	1,2284996	1,485 28	0.236562	0. 1575929
X _{B4}	354.803956	11,577,60	5,53227948	1,2284930	711.1977279	0	0	0	9.5766229	11,57715	1.64409316	.2284986	23,940572	0	0	0
T		41,986749	2,2293185	4,455384	0	73,4294752	2.27850223	9.11741402	11.57715	13.995583	2.2293185	485128	8	19.8996684	2.27850223	0.5316707
R _{B4}	5,53227948	2,2293185	1.005307/4	0.2365621	0	2.27850223	2.4745)086	0.2327457	1,84409316	2.2293185	0.35510236	0,736562		2,27850223	0.0395763	0.2327457
N _{B4}	1,2284986	4.4553840	0.2365621	0.4727787	Q	9.11741402	0.2327457	3,92080740	1,2284986	1.485(28	0,236562	0.1575929	•	0,53 6707	0.2327457	0.3525)577
X _{CA}	9,5766220	11.57715	1.8440936	1,2284985	9,5766229	11,577 5	1.84409316	1,2284986	1770.0247499	0	3,58818632		364,4705889	0	3.68618632	ß
Тсэ		12.2824313	1.5 08042	0.5133567	11.577150	13.995583	2.7293 85	1.485 28	0	31.4300976	0	4,78791436	0	<i>2</i> 7,99 66	0	2,970256
R _{C-3}		1.5 08042	0.07897280	0.0769458	1.84409316	2.2293 85	0,35510238	0.2365621	3.68848632	0	1.33583374	0	3,68818632	0	0.71020476	0
N _{C3}	1.2284986	0.5133567	0.0709458	D. 1499924	7284986	1.485128	0.2365621	0, 575929	. 0	4,78791436	0	7,1001926	0	2.970256	0	0.3151858
X	9.5786729	11.57716	1.84409316	1,2284986	73,94/5572	0	0	0	364.4705889	0	3.56615632	0 ,	607.2561707		0	0
Тва	11.577150	13,995583	2.2293 85	1,485 28	0	0.8996884	2.27850225	0.0316707	0	27,99\(66	0	z,970256	_ 0	53.5290068		8.56574332
R _{B3}	1.84409316	2.2293185	0.35510238	0.2355521	0	<u> 1.77850223</u>	0.0395783	0.2327457	3,68815632	0	0,71020476	0	. 0	0	2.43493250	0
N _{B3}	1.2784986	1.485128	0,2365021	0, 1575929	Q	0,5316707	D.2327457	0,35251577	0	2,970256	Q	0.3 5 858	0	8.5657433	0	4,77332326

QUADRANT A

- INDICATES NEGATIVE NUMBER

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X _{c2}		1	ĺ	l	T	Γ	Ι	9.5766229	11.57715	1.84400316	1 2284906	9,5766779	11 17718	1,84409316	(7784985
T _{C2}								11,57715	12.2824313	1.5(08042	0,5133567	11,577190	13,995563	7.7293185	1.485128
Rcg								1,84409316	1.5108042	0.07897286	0.0769458	1,84409316	2,2290185	0.35510238	0.2365621
N _{CR}							·	7.2284985	<u>0.5</u> 133567	0.0769458	0.1499924	1.2284086	1,485/28	0.2365621	0, 1575929
X _{B2}			1	<u> </u>				9,5766729	11.57715	1.84409316	1.2284986	23,3415572	0	0	0
T _{B2}								11,57715	3,995583	7.7793185	1.485128	0	9.4996504	2,27850223	0,53 6707
R _{b2}	· · ·	<u> </u>	<u>. </u>	<u></u>				1.84489316	2,2293185	0.35510230	0.2365621	Q	2.7/850773	0.0395703	0.7377457
N _{BS}								1,22,84986	1.485128	0.236562!	0. (575029	0	0.5316707		0,35251577
X _{c1}															
Tcı			٠.												
R _{CL}	1			L					,						
N _{CI}		i .								·					
X _{BI}		<u> </u>					<u> </u>		, .						
T _{B(}															
Rai						<u> </u>									
N _{BI}															
Y _A /2															
(Q _A /2)/T															

QUADRANT C

1	Ę _{C2}	U _{C2}	A ^{C5}	₩ _{C2}	ξ _{B2}	U _{B2}	V _{B2}	W ₈₂	ξ _{CI}	u _{cı}	Y _{CI}	WCI	ξ _{B1}	u _a ,	Y _{BJ}	W _{BI}	η _Λ	e _A r	-RHS
X _{C4}											<u> </u>				.		 		
TC4				,															
R _{c4} .											1					T			
N _{C4}																			
X _{B4}																	6.678900204	0	94,65079167
T _{B4}																	31,37288093	37.71758932	T
R _{B4}																	0,857401386		0,4 339 775
N _{B4}										,								4.002305972	
Хсз	9.5766229	11.577150	844093)6	1.2284986	9.5766229	11,577150	1,84409316	1,2284986			<u> </u>								
Тсз	11.577150	12.2824313	1,5108042	0,5 33567	11.577]5	3.995563	2,2293185	,485128									V 5. 1.	100	11 /0
R _{c3}					1.84409316						<u> </u>								
N _{C3}	1,2284986	0.5133567	0.0709458	0.1499924	1.2284986	1.485128	0.2365621	0, 1575929											
Хвз	9,5766229	11.577150	1.84409316	7284966	23.9415572	o l	0	0		Ľ						Г	16.124291456	0 .	228, 507224060
Твз	11.57715	13.995583	2.2293185	1.485128	0	19,6996684	2,27850273	0,5316707									12.995072772	37,71750932	
R _{B3}		2.7793185			0	2.27850223	0,0399783	0.2327457									2.069950004		0,99806026
N _{B3}	1.7284986	1.485128	0.7365621	0. 1575929	0	0,5316707	0,2327457	0.35251577			<u> </u>						1,378959739	4,002365072	0,664858651
									QL	JADRA	NT B						INDIC	ATES NEGAT	IVE NUMBER

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

· ————	:								·							1			
X _{C2}	(70.0247400	0	3,08818632	0	364,4705889	0	3,68818632	0	9.5766229	11.577150	. 84409316	.7284 0 86	9.5766229	11,57715	1.84400316	.2784986			T
T _{C2}	ρ	31,4300976		4.78791436	0	27.991166	0	2,9 7 0256	11,577 50	12,2824313	5108042	0.5133567	11.577[5	13.995583	2.2203185	.485 28			
R _{c2}	3,68818638	0	.33503374	0	3,68818632	0	0.7[020476	0	1.84409316	1,5108042	0,07897286	0,0769458	1.84409316	2,2293185	0.35510238	0,2365621			
N ^{CS}	0	4.78791436	0	2. 1891926	0	2,970256	O	0,3151858	1,2284986	0.5133567	0.0769458	D. 1400924	1.2284966	1.485128	0,2365621.	0, 1575729			
X ₈₂	364.4705669	0	3,68818632	0	687.2561707	0	D.	0	9.5766229	11.57715	1,84409316	,2284986	23,945572	0	0	0	16, 124291458	·Q	228.56722486
Тв2	0	27,991166	0	2.970256	0	53.5 298068	0	8,58574332	11,577[5	3,995583	2.2293185	485128	Q	19.8996884	2.77850223	0.5316707	12.MSB72772	37.71758932	
R _{B2} :	3.66618632	0	0.71020470	0	0	D	2, 4349325	0	1.84409310	z.2293 85	0.355/0238	0.2365621					2.069950004		0.9980 5020
N _{B2} i	0	2.970256	00	0.3151858	0	8.58574332	0	4, 27332326	1.2284986	1.485128	0.2365821	0, 575929),578959739		
X _{CI}	9.5700229	11.577[5	. 84469316	.2784986	9.5768229	11.577150	1.84409316	1.2284986	940.5670438	11,57715	,644093 6	.2284986	900.7535174		84400316		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
T _{CL}	11.57715	12.2824313	1.5108042	0,5133567	17.577150	13.995583	2.7793185	1,485128	11.57715	15.7150488	2.93263735	2.39395718	11.577150		2.2293185				
Rcı	1,84409316	1,5108042	0.07897788	0.0769458	1.84409316	7.2293 85	0, 355 (0238	0.2365621		2,9326373				2,2293185	0.35510238	0.2365621			
N _{CI}	1.2284986	0.5133567	0.0769458	0. 1499924	1.2284000	1.485128	0. 2365 07 1	0. 1575929		2.393957[8					0,2305621				
X _{B1}	9.5766229	11.577 5	.84409316	1,2284966	23.94/5572	0	0	0	200.7535174	11.57715	1.84409316	.2284986	818,7507877				8.678900204	П	94.65079167
TBI		13.995583	7.2293185	1.485128	0	19,8996684	2,27850223	0.5318707	11 577150	13.995563	2.2293105	.465/28	23, 15430					37.71758932	
R _{BI}	1,84409310	2.2293185	0.35510738	0.2385621									3.6061864						0.413391779
N _{B1}	1,7284986	1.485 28	0.2365621	a, 1575929									7. 4569972						
_ _A ^5	<u> </u>													1,144			72,3905188	0	34,9096W62
2 ₄ /2)/r	~~~			i							ii							152.4713037	1

QUADRANT D

--- INDICATES NEGATIVE NUMBER

TABLE 2.- OPERATIONS TABLE FOR CYLINDER 39 WITH 45° CUTOUT.

	Ę _{C4}	U _{C4}	V _{C4}	W _{C4}	5 84	U _{B4}	Y _{B4}	¥ ₈₄	ξcs	u _{c3}	V _{C3}	W_3	₽83	U _{B-5}	Y _{B\$}	¥ _{B3}
Xcs	1779.6013728	11,577150	5.53227048	1.2784956	.54.893966	JL.577150	5.53227948	7.7284986	9.5766229	U.57715	1,84409316	1.2284086	9.5768223	11.577[5	1,84409316	1,2284900
TG4	11.577150	43.7(25289	1.5/08042	5.30 27 06	11.577150	41,985740	2,2293185	4.455384	11,577/5	12.2824313	1,5108042	0.5 33567	11,57715	13,995583	2.2293 85	1.485(28
R _{c4}	5,53227948	1.5 108042	1.41480662	0.0758458	5,53227948	2,2293 85	1.06530714	0.2305621	1.84409316	1.5]08042	0,07897288	0,0769458	1.84489316	2,2293185	0.35510238	0.2365621
N _{C4}	1.2284986	5,30 27 06	0.0769458	2,0392002	1.2284986	4,455384	0.2305621	0.4777787	1.2284986	0.5 33567	0.0769458	0.1499024	. 1,2284966	1,485 28	0.736562	0, 1575029
X _{B.4}	364,803966	11,577,50	5,53227948	1,2284930	711.1977279	1	O	0	9.5766229	1,577 5	1,84409316	.2264946	23,945572	0	0	0
Tpg	11,577 50	41.986749	2.2293185	4,455384	0	73.429475Z	2,27850223	9.11741402	11.57715	[3.995583	2,2293[85	1,485128	. 0	19,5096684	2,27650223	0.6316707
R _{B4}	5,53227948	2.2293185	1,005307/4	0.2365621	0	2, 2785072 3	2.47451080	0.2327457	1,84409316	2.2293185	0.355(0238	0.7365621	ı	2,27850223	0,0395783	0.2327457
Na	1.2284986	4,4553840	0.2365621	0.4727787	.0	9.1741402	0.2327457	3 97080749	1,2284986	1,485 28	0.2365621	0.1875920	0	0.53(6707	0.2327457	0.35251577
X _{C3}	9,5766229	11,57715	1,84409316	1,2284986	9,5766229	J1.57715	1.84409316	.2284086	170.0247499	0	3,56818637	. 0	364,4795880	0	3.05810632	D
Тсэ	11,57715	[7.28243]3	1,5108042	0.5133567	11.577150	13,995583	7.2293185	1.485128	0	31.4300970	0	4,78701436	0	27.991165	0.	2,970256
R _{C3}	1.84409316	1.5108042	0.07897288	0.0760458	1.84409316	2.2293 85	0,35510238	0.2365621	3,688(8632	0	1.33583374	0	3.68818632	0	4.71029478	0
N _{ca}	1,2284986	0.5133567	0.0769458	0.1499924	7.2284986	1.485128	9,2365021	Q. 1575029	0	4.78791436	0	2,1891926	0	2,970256	0	0,3 5 858
X _{B3}	9.5766229	11.577/5	1.84400316	1.2284986	23.94(5572	0_	0	0 .	364.4705889	0	3.000/0032	0	807.2561707	0	0	0
T _{B3}	11,577150	13.995583	2.2293185	1.485 28	Q	19.8996684	2,27850223	0,5316707	0	27.99) 66	0	2,970256	0	33.5298068	1	8,56574332
R _{B3}	1,84409318	2,2293185	0.355 0238	9.2365521	0	7.27850223	0,0595783	0,2327457	3,688(8632	0	0.71020476	0	0	0	2,43493756	0
N _{B3}	1.2284986	1.485128	0.236502)	0.1575929	0	0,5316707	0.2327457	0.35251577	0	2,970256	0	0,3 5 858	0	8,5657433	0	4.77332326

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,							
9,5766229	11.577)5	1.84409316	1.2284986	9.5756229	11.57715	1.84409336	1,7284986
11,577/5-	12,2024313	1,5108042	0.5133567	11.577150	13.995583	2.2293185	1,485128
1,84409316	1.5108042	0.07897286	0.0769455	1.84409316	2,2298185	0.36510738	0.236562
1.2284986	0.5133567	0.0769458	0.1499924	1.7284966	1,485128	0,2365621	0,1575929
9,5766229	11.57715	1.84409310	1,7284986	23,94,5572	0	0	0
11,57715	13.995583	2.2293185	1,485 28	0	19.0998604	2.27850223	0.53(6707
1.84489316	2.2293(85	0.35510238	0.2365021	Q	Z.Z/850ZZ3	10.0395/83	0.2327457
	1.485 28	0.2365621	0.1575929	0	0.5816707	0.2327457	0.35251577
1							
<u> </u>		~~ - -			<u> </u>	 	
 		†			<u> </u>		
+	 	 					
	11,577/5- 1,844093/6 1,2284986 9,5766229 11,577/5	11.57/15- 12.2824313 1.84409316 1.5108042 1.2284986 1.5133567 9.5766229 11.57715 11.57715 13.995683 1.84499316 2.2293185	II.57/15~ IZ.2624313 1.5108042 0.07697286 II.2284986 0.5153567 0.0769458 9.576629 11.57715 1.3440340 1.57453 1.57715 1.5440340 1.57723185 1.54489346 0.35510230 0.35	TI.57715 12.2824313 1.5108042 0.573367 T.84409316 T.5108042 0.0769428 0.0769458 0.0769458 0.0769458 0.1499924 9.5766729 11.57715 T.8440310 1.2284986 1.2284986 1.2284986 1.465128 1.465128 1.465128 1.465128 1.465128 1.265128	II.577/15 IZ.26243/3 1.5108042 0.5133567 II.577/150 I.844093/6 I.5108042 0.07697286 0.0769458 I.0769458 I.0440936 I.2284986 0.5133567 0.0769458 0.1409924 I.7264066 9.5766729 11.577/15 I.8440936 1.2284966 23,94/6572 11.677/15 13.995683 2.2723/85 1.485/28 0 1.84893/6 2.2723/85 0.355/0236 0.2365/021 0		II,57715 IZ,2624313 I,5108042 0,5133867 II,577150 I3,995583 Z,7213185 I,84409316 I,5108042 0,07897288 0,0769458 I,6440336 Z,7293185 0,32510238 I,2284986 I,5133567 0,0769458 0,149924 I,7284986 I,485128 0,736821 9,5768729 II,57715 I,6440130 I,7284986 23,9415572 0 0 II,57715 I3,995583 Z,7293185 I,485128 0 I9,096604 Z,77850773 I,84499316 Z,7293185 0,35510230 0,2365021 0 T,77850723 0,0395783

QUADRANT C

				TABLE	2 OP	ERATIC	INS TA	WBLE F	OR CYL	INDER	39 WI	TH 45°	, COLO	<u>UT Co</u>	nclude	<u> </u>			
i	€c₂	U _{C2}	V _{C2}	¥ _{C2}	ξ _{B2}	U ₆₂	V _{B2}	¥ _{B2}	Ę _{CI}	ü _{C1}	A ^{CI}	W _{C1}	ξBI	ü _{BI}	Y _{B1}	W _{Est}	ı,	ø,r	-RHS
X _{C4}														ļ	ļ	ļ	<u> </u>		
TC4		İ							<u> </u>	<u> </u>				<u> </u>	ļ				
R _{C4}													_,	<u> </u>		<u> </u>			——i
N _{C4}										<u></u>	<u> </u>			<u> </u>	<u> </u>	ļ	ļ		
X _{B4}			<u> </u>								· .					ļ	6.678900204	0	94.05070057
T ₈₄												L				<u> </u>		37,7175 89 02	15, 12027643
R _{B4}							•										0.85740 300	0	0,413391775
N _{B4}														<u></u>			3.329103300	4,00730907	1,505110773
×α	9.5766220	11.577150	,04409300	,2784968	9,5766729	11.577750	1,84409316	.2784988	·			ļ		<u> </u>		ļ <u>.</u> .			
Tes	11.577150	12.2824313	.5108042	0,5133567	11,57715	3,99553	2,2293185	465178			<u>.</u>	ļ		<u> </u>	<u> </u>	<u> </u>		<u>'</u>	<u> </u>
R _{C3}	1.04409310	1.5108042	3,07897288	0,0760458	1.84409940	2.229365	0,39510238	0.236562		L		ļ			<u> </u>	<u> </u>			
N _{C3}	1.2284986				J.2284986					ļ	<u> </u>	<u> </u>		<u>. ,</u>		<u> </u>	ļ	<u> </u>	
X _{B3}	9,5768229	11.577/50	1.844083(6	2784986	23.9419572	0	0	0	•					<u> </u>	J	ļ	16,124281456	<u> </u>	778, 507724860
1 1 1 1 1	11.57715					19,0996884	2,278,022	0,3316707	<u> </u>	<u> </u>	1.	L	<u></u>	<u>' </u>	<u> </u>	<u> </u>		37,71750932	
R _{B3}		2.7793185	0.35510236	0.730662	_0	2,27850223	0,0385783	0,2327457	L		<u> </u>		L	<u> </u>	<u> </u>	 	2,05995000		0.99809026
Neg		1.485428			0	0.5316707	0.2327457	1.3525157	d		<u>l</u>	L	<u></u>	1	<u>L</u>	1	3/1959/3	4,00236697	0.00485065

QUADRANT B

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NATIONAL ADVISORY COMMITTEE FOR AERONALITIOS

																<u> </u>				·
X_;	170	.0247499	0	3,66618632	0	364,4705889	Ð	3,60018632		9,5706229	.5771 5 0	1,84400316	.7284986	8.5766229	1,57715	1.84400318	,2184986			
70			31,4300076	0	1,78791430	0	77,99 1,86	0	2.97075 6	11,577150	2,2824313	5106012	0.5133567	JJ.577 <u>/</u> 5	3,995583	2,2203185	465126			ļ <u>.</u>
R _c	. 3	.688/632	0	.33583374	. 0	3,68818632		0,71020476	D	1,84409310	1,5108042	0.07897286	0.0769458	J.84409386	2,7298 (8)	1.355 10738	0,2365021			
N _C		0	4.76/9430	0	2, 1891926	0	2,970258	0	0.3151858	1,2284986				1,2284986	1.405 23	0,236562L,	0.1073729		· · · · · · · · · · · · · · · · · · ·	
XB	364	4705889	0.	B 650 800	0	687.2961707	•	0	0	9.5766229	11.57715	.84408310	.2284900	23,945577,	0 .	0	0	0, 124791450	!	224.5072400
T _B ;	,	1	27:09(166	0	2,870256	1	13,5798086		1,58574332	11.57745	3.90563	2,2203185	.465120	1	9,6996864	2,27850725	0.5316707	2.808072772	37,71760932	0.7078843
R	3	6051863	0	0.71020470	O	0	6	2.4349325	8	1,84409310	2.7293185	0.35510734	2365621				****	2.069050084	Q	0.99800526
N _B	1	0	2,970256	0	1.3 5 854	В	8.5857438	0	4.27332328	1.2284966	1.485128	0,2305821	0.1675929	0	0.53(6707	1.2327457	0.35251577	370000730	4.002305972	0.66485005
X_		.5700E20	11,577(5	54409316	.2284966	9,5766229	11.577150	84400315	.2284000	0411.5670438	11,57715	.84409318	,2284900	300.7935174	11.57716	,84400316	.7264966			
Тс	ı îi	.57715	12.2824313	1.5108042	3,5133507	JT.577 90	13. 095963	Z. 2793185	, 465 i Z	11 57715	15.7150468	2.93203735	2,3939574	11.377750	3.905583	2,2293185	1,465 28			
R _c	Ĭ	.84483310	1.5108042	0.07097280	9.0709458	1,84409315	7,7273135	Q 355 W23	D.236582		2,0326373				2,2293 85	1.35510234	0.2303021		<u> </u>	<u> </u>
N _C		2264586	0.5133567	0.0769458	1.1499924	1,2284906	1.445(28	1,7365621	0.1579929	1,228,4926				1.2284966		0,2305621	0, 1575029			<u> </u>
X	وار	,5700229	11.57715	84400306	.2284986	23,9415572		1 0		560.7535 <u>174</u>				518.7587877	3 5430	3.06812632	2,4500972	5.078900004	O	94.65079107
Ť		.577(50	13,995583	2,2293105	1.485128					11.577150					45,4383092		B. 147 581	31.37260003	37,71750032	15.12007513
R		84409318	7,2293185	0.32710230	0.7.50302)		2 7785022	0.0305763	9.2327457	1.84489316	2,2293105	0,356 07.38	0,2305021	3.588(864	1,4370286	764300)	0.6270 58	0.85740(366	0	0.413391775
N _a		2284986	1,425(28	1.2365021	0.1575029		0.5316767	0,2327457	0.3575 1577	7.2284086	1,485128	0,2365621	0. <u>1575929</u>	<u> 1.4569977</u>	8.147/58	0.6270(58	3.00562[6	3.322 (13385	4.002305977	1.865/10773
Y]						: 		ļ <u>. </u>		<u> </u>	<u> </u>	<u> </u>	.	77.3965188		31,00001462
$(\mathbf{Q}_{\mu}/2)$	r.	-		1	l	<u> </u>] 		<u>i</u>	¦ L.,		· ·	<u></u>		! •		!	<u> </u>	02.47(3037	0

QUADRANT D

--- INDICATES NEGATIVE NUMBER

TABLE 3.- OPERATIONS TABLE FOR CYLINDER 40 WITH 135° CUTOUT

	Ę _{ca}	U _{C2}	A ^{CS}	W _{C2}	ξ ₈₂	UBR	V _{B2}	W _{B2}	Ę ₈₁	u _e ,	V _{B1}	W _{B1}	n,	ø _A r	-RHS
X _{C4}			Ī								Π.	\sqcap			
T _{C4}										T	Ī				
R _{C4}											1		1		
N _{C4}								- 1		Ì	<u> </u>				
X ₈₄													6.675800294	0	94.65079 67
T _{B4}				-							l		37788093	37.71758932	
R _{B4}													0.857481366		0.4[339]775
N _{B4}													3.3201033 85	4.002365977	1,805110773
Х _{СЭ}	9,57662729	11.577160	844093	.7784986	0,5756229	11.577150	.84409316	.2284966							
Т _{С3} -	11,577(50	2.7884313	1.5/08042	0,5133667	[1.577]5	3.005563	7,7293185	,485128						•	, , , , , ,
Rcs					1.84400310					1					
N _{C3}		0,5133567													
Хвэ					23.94 5572	0	0	0					18, 124291450	0	278,507724860
Tag		3,99583				9,0096684	2.27850223	1.5316707					2.995072772	37,71758932	6,2655643
R _{B9}		2,2293 85				2.27850223				I			2,068958004		0,9960 6026
N _{B2}		1,485128				0.53 6707]		1.378059739	4,002365972	0.56485865

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						1									
X _{C2}	940.5670438	11,57715	.84409316	.7784986	304,7535174	1 57715	.84 400 316	1,2284986					7		
TCE	11.57715	5.7150488	2.9320373	.39395/18	11,57715	3.905583	Z. 2293 (85	.485128							
R _{C2}	84408316	2.93763735	0,6670(887	0,7020249	1,84409316	2,2293/85	2 35510238	0.2365621							
NCE	1.2284008	2,39395718	0,7020249	,0945963	1.2284966	1,485128	1,236562	9 575929							
XBS	300.7535174	1,57715	.84 40 93 6	.2284086	305,3858534	11.57715	I, 844 <u>893</u> (6	12204026	14,,3640343].577 5	.84400316	,2284986			
T _{B2}									11.57715						
R _{B2}									1.84409316						
N _{B2}									1.2284986						
Xcı									290.8440245						
Tcı	,		-						11.577 5						•
R _{CI}									5.53227048						·
N _{CI}									1.2784985						
XBI	-														
Tal											•				
R _{BI}	-														
N _{BI}															
Y_/2									•						
(0,/2)/1														<u> </u>	-
											· · · · · · · · ·				

QUADRANT D

--- INDICATES, NEGATIVE NUMBER

TABLE 4	OPERATIONS.	TARIF FOR	CYLINDER :	SE WATU	90° CUTOUT
INDUCE T.	OLLIVAINIS	IADLE FLA	TATE IN THE PERSON OF THE PERS	SS WILH	MH 17 (3) (1) (1)

1		, 1																
	2u _{Bi}	28 52	Ę	U _{B2}	V ₃₂	W ₈₂	Fcz	U _{C2}	A ^{CS}	AC5	ξ ₈₃	U _{B3}	Υвэ	W ₈₃	₽ _{C3}	u _{c3}	V _{C3}	W _{C3}
T _{B1}	51.0772816	11.23007484	D. 1543	JI .8081706	0.49636746	1.9000148												
		7.9162748	7.4508977	1.9060146	0.9386(354	1.0202 734												
Xaz	73. 1543	2.4569972	640.748991	JI.57715	.844093 6	7.784908	Z52.8 82 5472	11.67014]5	0.91714628	0,2905633	47.851144	0	8	0	19.1532456	11,0701416	0.91784820	0,2985833
T _{B2}	1,8081708	1.9000146	17.577/5	100, 14045767	14.78452B33	14.01338468	11.8701418	7.11065847	0.5502470	1 10 192727	8	72.64330253	15.94 168984	10,85475158	11.6701418	7.11065447	1,5592470	0.18192727
Rag	0,09836748	0.93861954	1.84409310	14.78452633	4,60220514	1.77 56578	0.91784628	0.3502470	0.04398434	0.01430848	0	15,94168964	2.9474059	1.52788416		0.9992470		
	1,9069146	1.0202 734	1,2284968	14,01338186	1.77150579	5.132718547	0.7909653	6. 18192727	Q.01430846	1.0048 548 905	0	10.85475550	1.52768418	0.582867183	0.2585633	0.18192727	0,01430646	0,0046648905
X _{C2}			252,8975472	11.8701416	0.91784020	1.2965633	534,6906248	1.6701416	0.91784628	0.2985833	19.1532456	11.87Q1416	0.91784628	0.2985838	19. [532458	11.5701416	0,91764621	0.2900033
T _{CR}			11.6701416	7.11085847	0.5592070	0.10192727	11.6701416	49.37067847	1.931096	5,83314177	11.6701416	7.1108569	0.5592470	0.18192727	11.6701418	33, 13 65 7(53	7.677637	5.39705483
R _{C2}			0.91784628				0.91784628				0,91784828	0.5992470	0.04390430	0,01430846	0.91784828	7.877857	,46637728	0,76155734
N _{C2}	_		8,2965833	0.18192727	0.01430640	0.0046546905	0.2985833	5.63314177	1.43248446	.57780089	7965633.	0.18197/7/	0.01430645	8.8848548905	0.2985833	3.39795483	1.7615734	0.29065781
X _{B3}			47.8831144	8		G	19.1532456	670/416	0.91784628	0.2985633	838.402547 7	0	0	0	431,2528581	8.09299 16	2,78193044	0.9299 53
Tu			0	72,64336253	15.94 (68964	0.85475150	11.5701418	7.11085817	0.5502470	0. 1819 <i>272</i> 7	0	73, [3004007	7.55520783	15.49051288	0.9929916	21,10824147	.670075	66705627
R _{B3}			p	5,94 68964	2.94740590	1,52788418	0.01784828	0.5592470	0.04395434	0.01430646	. 0 .	12,53520763	4.95/30/52	1.53500371	2,751/3944	1.67007)5	0.3990672	1,22225382
N _{B3}	4	· '	0	10,85475158	1.52788418	0,502007183	0.2905033	0,18192727	<u>0.01430846</u>	0. 0048546 905	0	13.40651286	1.53500371	5,290311447	0,0200 (53	1.88705927	. 7.272.538£	D. 162247590 5
Xca			19, 1537458	11.6701416	0.01764624	0,2985833	19.1537456	11.6701416	0.91764628	1.2985833	13],2528581	0.0029016	2.7619394	0.9299153	1408.878049	9.09295]6	1,76193944	1,9299[53
Tcs	····		11.6701416	7,11083647	0.5592470	0. 18192727	11.6701416	95. 3857 93	7.877637	5.30705468	0.0020010	21.10024147	1,070075	1.06700327	0.09299/8	M.04572727	5,99925865	t.02709805
R _{ca}		•	0.91784628	0.5592470	0.04398434	0.01430646	0.9)78490	7.677637	46637226	0.70155734	2.76193944	1.6700715	0.399056/2	0.22225382	2.76193944	5.99025865	Z: 543 80C	0.73045058
N _{G3}			0.2985833	0.18192727	0.01430646	0,0046546905	0.7905633	5.39705468	0.76150734	0. 200 05/61	0.9299 53	1.66700027	0.22773862	0. 162247590 0	0.9299153	8.02709 00 5	0.73045950	2.672 989906

QUADRANT A

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		, .	·														
X _{B4}						<u> </u>	·	<u> </u>		23.0415572	. 0	0	0	9.5766220	11.57715	1.84409808	. 728 4986
T _{B4}			•]						0	19.8909004	2,27830223	0.53 6707	11.57715	3.995563	2,2293105	.485128
R										מ	2.27850223	0.0395783	0.23274560	11.57715 1.64408316	7.2283185	0.35510230	1,23656200
N _{B4}			[•					8	0.5316707	0.23274569	0.3325677	1.2284988	1.485128	0.23656200	0, 15758290
X _{C4}		•						.].		(1,577)5			0.5708220	11,57715	1.84400318	.2784966
TCA]				Ţ			13.995563			11.577[5	2.2824313	1.5108042	0.5133567
R _{C4}										1.64409310	2.2203/85	0.36510235	0.23656806	1.84400310	1.5108049	0.07497288	0.0789458
N _{C4}													0, (5759290			0.0769434	
X _{B5}																	
Tab	- -									 			*	,		1	
R _{B5}								1		· ·					 -	 	
N _{BS}					-	· · · · ·		 		 							
X _{cs} .		_			~		1	 	ļ	-						 	
Tci				——i		· · · · ·	 			 						 	
Rcsi	!	-		~		l	 		 	l		 -				 	
N _C		 				†	 	 	 	 						-	
N _{C8} Y ₄ /2 P ₄ /2}/T						 	 	 		 						+ 1	
Q.72/m							 	+	 	 		 -					
~~		ــــــــــــــــــــــــــــــــــــــ				<u> </u>	<u> </u>	1.000	ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ ـ 	<u> </u>		نـــــــن		i		ليبين	

QUADRANT C

--- INDICATES NEGATIVE NUMBER

TABLE 4 OPERATIONS TABLE FOR CYLINDER 35 WITH 90° CU	JTOUT - Concluded
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	584	Ü84	Y ₈₄	₹84	5 _{C4}	U _{C4}	Y _{C4}	C4	505	U _{BS}	V _{9.5}	W _{8.5}	Ecs	U _{CS}	Ycs	W _{CS}	٦٨	₽ _A r	-RHS
T _{B1}																-	33,95778161	37,71750034	16,37236254
N _{BI}																	3,603 32545 4	4,00236597	1,73735938
XBE																	8, 5043 88	Q	212.9082457
TBR		Ĺ.,,								<u> </u>					I		ZZ.2257845	28.35302063	10.7/604998
R _{B2}			<u> </u>											!	Ĺ		2,29180564	2,25830575	1.10500672
N _{B2}										L					Ĺ	<u> </u>	1.938940664	2,74437357	0,9334044
X _{C2}		<u> </u>							. =	<u> </u>					1				
Tca															1				
R _{C2}																			
N _{C3}											-								
X _{B3}	23. 94 5 577	0	0	0	9.8766229		.84400810	,2284980						Ĺ			12.91897017	0.	277.0845833
Tea	0	9 8998684	2,77050223	0.5316707	11,577 <i>1</i> 5 1,84 4093 (8	13,005563	2.2200065	,480178									5.2469037		2,5207007
R _{B3}	0	2.27830223	0.0395783	0.23274569	1.8440030	7,2293 85	0.35510238	1.23000200						L			0,41266436	2,25639575	0.19808406
N _{B3}	0	0.5346707	0,23274569	0.35251577	1.2284986	,485 28	0, 23656200	1,15759291									0.134242930	2.24437350	0,064724722
X _{C3}	9.5706229		1,84400310		9.5766229														
Tc3	11,5775	3.905583	2.2293785	.485 28	11.577 5														
R _{CIL}	1.84408316	2.2203(85	0.355 (0238	0,23656 20 8	1.84409385	1.5108042	0.07097201	0.07694562		.									
N _{G3}	1.2284986	1.485128	0. 23656206	0. 15759200	1.2284988	0.5133567	0.07604502	1,1499024		<u> </u>				<u> </u>					

QUADRANT B

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

												r	<u>_</u>	·					
X _{B4}	1070,0009874	0	0	0	594, 1570575	0	3,000,0632	0	23,9413572	0	0	0	9,5760729)[,577]]	.04409310	. <u>2284</u> 900	16. 12420 491	0	360,97564828
T ₈₄	0	53.7288068	0	0.565 M332	0	27,991,666	0	2.97 0256	0	9.8906684	2.27000 223	9,5316707	11,577)5	13,995583	2,2793 85	.465 28	12.99507275	37.7(7589328	0.2655084
RB4	٥	0	2.43483256	0	3.8888832	ď	0.71020470	0	0	2,27020223	2.0395763	0,737/4:00	1,84408310	2.2283 85	0,35510238	0.23858208	2.06 099 0004	8	0.99996020
N _{B4}	0	0.5857(332	0	4,27332326	۵	2.970250	0	115188	8	0.5316707	A. 23274500	1.35251577	1.2284966	1,485128	0,23050200	D, (5 7592 90	1,17805973	4,002305972	
Xc4	594.1570675	0	3,666,6637	Q	1859.0841887	0	7 00010055	0	9.5766229	11,57715	1.04409316	7,2284906	9,5798229		.04409310				
T _{C4}	0	27,901(6 5	0	2,970256	8	31.43 0007 6	0 *	4,78791436	11.57715	3,095583	2.2293485	1,455128		12.2024313	.5100042	0.5133507			
R _{C4}	3.88648637		0.7102047 6	ø	3,888/8832	0	,3565374			2.2293/85	0.35510238			5 108042					
N _{G4}	Û	2.970756	Ö	0,3 5 858	0	4,70791438		2,1891925	1,2204986	1.485128	1,23550208	0.1575029	1.7284965	0,5 33967	0.0789458	0./499924		·	
X _{B5}	23,9415572	0	0	0	9.5766229	11.57715	1,64408316	.2234986	0094.00065246	0	0		584,5004446				6,67000020	0	153,24803 32
Tes		9.899664	2,77850223	9.53/5707			2,2293185			73.4294752	Z. 27050223			41,986749		_	JI.37288093		
R _{B5}	0	2.27850233		0, 23274500		2,2293185				2.27650223									0.413301773
Nos		0,53(6707	0.23274569	0.35251577	1.2284905	1.486(28	0. 23656700	0. 1575929	0	9,3691825	0.23274569								
X _{cs}		11.57715	,84409316		9,5766229		i.6440931 6	.2284988	504,5804446	11,57715	5,53727948	. ZZ6496 6	J558, 860,4086		3377794	******			
T _{C5}	11.5//15	3.995555		.455 28	11,57715	12.2024313			11.57715	41.905749	Z.2293185			13.7125280					
R _{cs}	1,84409316		0,35510238		1.844893/6	1.5/08042	O. <i>174912</i> 83	1.07604562		2.2203180	1,00630714			1.5106042					
N _{C5}	1,2284986		0, 23656206			0.5133567					9,73656208			5.30127100				•	
Y _A /2	15.124291450	2.000/775	Z. 000050 004	1,378999735						31,37200093							45.8007/006	9	70,20051464
(Q, /2)/1		37.71752030		4,007,365970						57.717 569 32		1,08730587Z						394.94259769	0

QUADRANT D

--- INDICATES NEGATIVE HAMBER

TABLE 5.- DEFLECTIONS AND ROTATIONS FOR

CYLINDER WITH 45° CUTOUT

M = 5075.45 in.-lb; η = 0.934679; θ r = -0.182954; unit for values is 1×10^{-3} in. or radian

		Ring A	Ring B	Ring C
Stringer 1°	ร น v	-0.382683 .680577 .357683 018295	-0.211436 .000999 .000110 013137	45° cutout
Stringer 1	un U ¥	.382683 .680577 357683 018295	.211436 .000999 000110 013137	0.070479 145643 050187 012965
Stringer 2	\$ U V	.923880 .174729 863531 018295	.462027 086238 232744 028647	.154009 176519 024713 013301
Stringer 3	š u v	.923880 540637 863531 018295	.461874 269938 185258 010892	.153958 183646 .002972 016637
Stringer 4	š u v	.382683 -1.046485 357683 018295	.191394 376640 086306 020508	.063798 179948 .003054 018817
Stringer 4.	u v w	382683 -1.046485 .357683 018295	191394 376640 .086306 020508	063798 179948 003054 018817

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TABLE 6.— DEFLECTIONS AND ROTATIONS FOR CYLINDER WITH 90° CUTOUT

[M = 7845.90 in.-lb; η = 0.877023; θ r = 0.128525; unit for values is 1 × 10⁻³ in. or radian]

		Ring A	Ring B	Ring C
Stringer 2	u v w	-0.707107 .748674 .620149 .012853	-0.443778 .316729 139502 081652	
Stringer 1	\$ U V	0 1.005548 0 .012853	0 .133452 0 .123108	90° cutout
Stringer 2	u v w	.707107 .748674 620149 .012853	.443778 .316729 .139502 081652	0.147921 .396281 614729 .095219
Stringer 3	t v w	.923880 .464147 810264 .012853	.462609 .275678 —.327575 —.055475	.154210 .203256 356365 .093722
Stringer 4	\$ ₩	.923880 207097 810264 .012853	.461645 .034594 —.088412 .057352	.153875 .128796 .092635 .032331
Stringer 5	ţ u v	.382683 681739 335622 .012853	.191577 003785 088206 .000093	.063867 .189788 .020932 .006447
Stringer 5	ţ u v	382683 681439 .335622 .012853	191577 003785 .088206 .000093	063867 .189788 020932 .006447

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TABLE 7.— DEFLECTIONS AND ROTATIONS FOR CYLINDER WITH 135° CUTOUT

[M = 4511.04 in.-lb; η = 0.780683; θr = -0.02370; unit for values is 1×10^{-3} in. or radian]

		Ring A	Ring B	Ring C
Stringer 2°	\$ u ♥	-0.923880 .275052 .721257 002370	-0.511401 .142873 .276732 093973	•
Stringer 1	\$ u v	382683 .697557 .298752 002370	381188 095065 652765 .045670	135 ⁰ cutout
Stringer 1	ž V W	•382683 •697557 —•298752 —•002370	.381188 095065 .652765 .045670	
Stringer 2	\$ u ₩	.923880 .275052 721257 002370	.511401 .142873 276732 093973	0.170466 .057603 099144 .025017
Stringer 3	š u v	.923880 322452 721257 002370	.461519 075011 035912 .054762	.153841 .043337 .061874 .022328
Stringer 4	t u v	.382683 744957 298752 002370	.191637 067597 049547 015939	.063876 .120387 .088380 003614
Stringer 4*	#5 ¤ ₹	382683 744957 .298752 002370	191637 067597 .049547 015939	063876 .120387 088380 003614

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TABLE 8.— AXIAL DEFLECTIONS FOR APPROXIMATE SOLUTIONS [Unit for values is 1×10^{-3} in.]

Angle of cutout	Stringer	Ring A	Ring B	Ring C	Average moment (in.—lb)
	1	0.382683	0.206436	0.071479	
	2	.923880	.432027	.0142009	
45°	3	.923880	.431874	.140958	
	4	.382683	.179394	.058798	
M(inlb)		5392	4788	4696	4959
	1	0	o	0	
	2	.707107	.426278	.143121	
	3	•923880	.450609	.149910	
90°	Ъ.	.923880	.443144	.146275	
	5	.382683	.183577	.060567	
M(inlb)		8155	7586	7533	7758
	1	.382683	.341188		
	2	.923880	.484401	.160466	
1350	3	.923880	.433019	.142341	
	4	.382683	.179637	.059176	
M(inlb)		4875	4272	4206	4451

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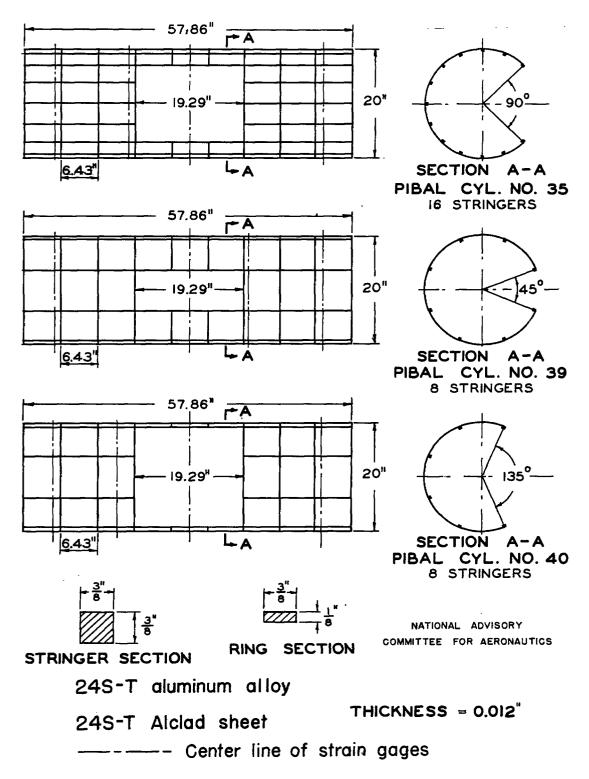


Figure 1.- Actual monocoque cylinders. (Described in reference 8.)

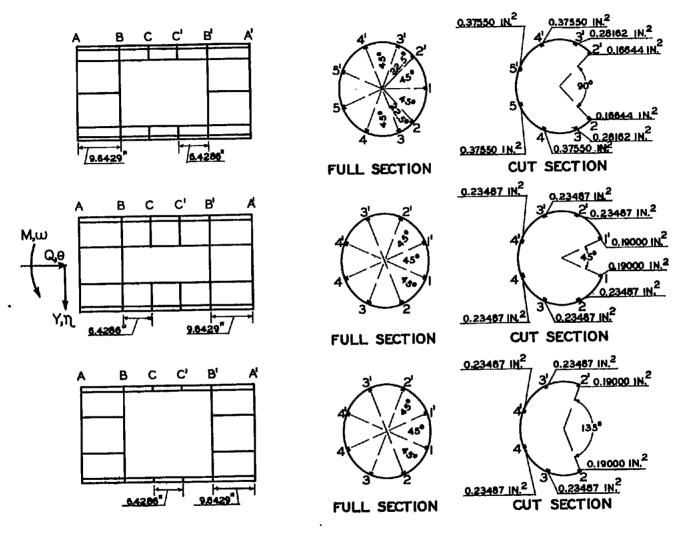


Figure 2.- Modified monocoque cylinders.

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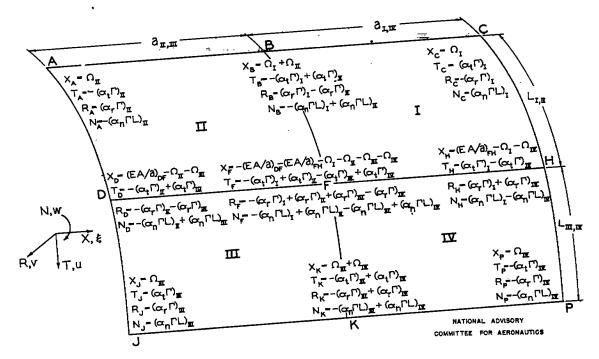


Figure 3.- Effect of unit axial displacement of F. Forces and moments acting on constraints. $\Gamma = \frac{Gt}{2}; \quad \alpha = \frac{Gta}{4T}.$

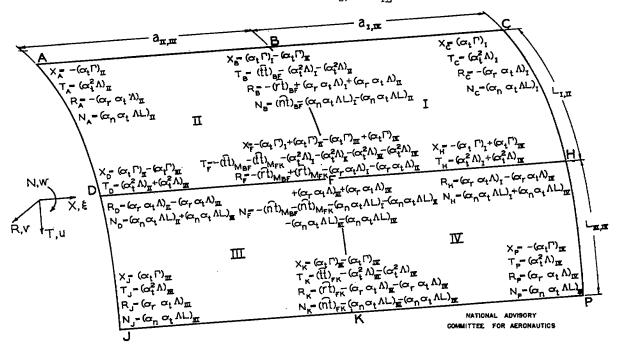


Figure 4.- Effect of unit tangential displacement of F. Forces and moments acting on constraints. $\mathbf{r} = \frac{Gt}{2}; \quad \mathbf{\Lambda} = \frac{GtL}{2}.$

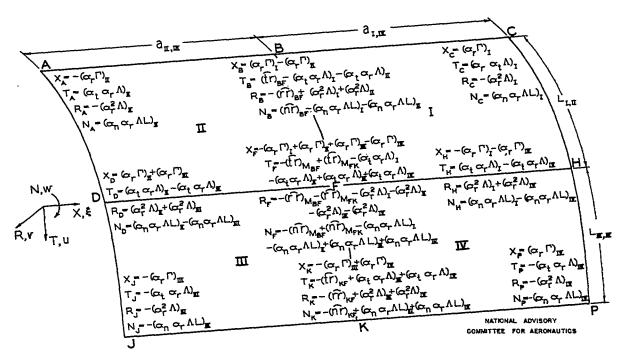


Figure 5.- Effect of unit radial displacement of F. Forces and moments acting on constraints. $r = \frac{Gt}{2}; \ \Lambda = \frac{Gt I_{\perp}}{2}$

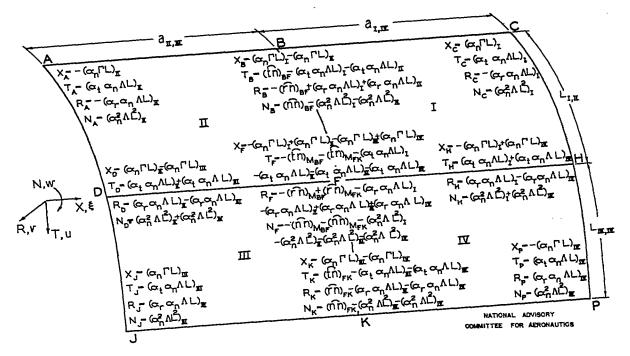


Figure 6.- Effect of unit rotation of F. Forces and moments acting on constraints. $F = \frac{Gt}{2}$, $A = \frac{GtL}{2}$.

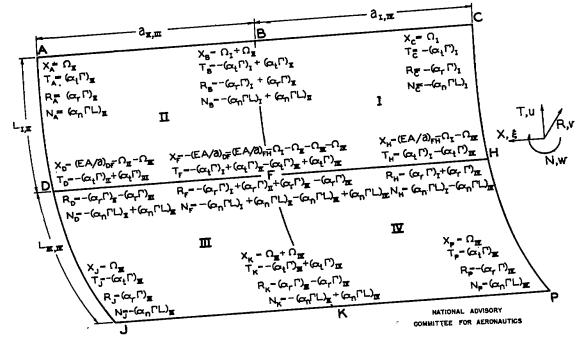


Figure 7.- Effect of unit axial displacement of F. Forces and moments acting on constraints. $r = \frac{Gt}{2}; \ \ \alpha = \frac{Gta}{4L} \ . \ \ \text{(Curvature opposite that in figs. 3 to 6.)}$

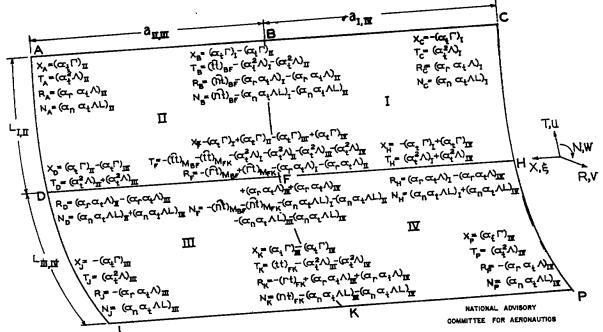


Figure 8.- Effect of unit tangential displacement of F. Forces and moments acting on constraints. $\Gamma = \frac{Gt}{2}; \quad \Lambda = \frac{GtL}{a}. \quad \text{(Curvature opposite that in figs. 3 to 6.)}$

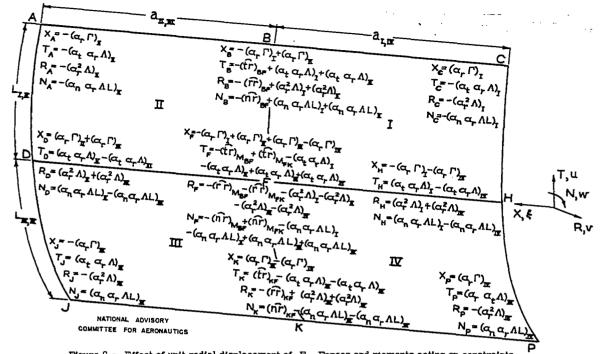


Figure 9.- Effect of unit radial displacement of F. Forces and moments acting on constraints. $r = \frac{Gt}{2}; \quad \Lambda = \frac{GLL}{a}. \quad \text{(Curvature opposite that in figs. 3 to 6.)}$

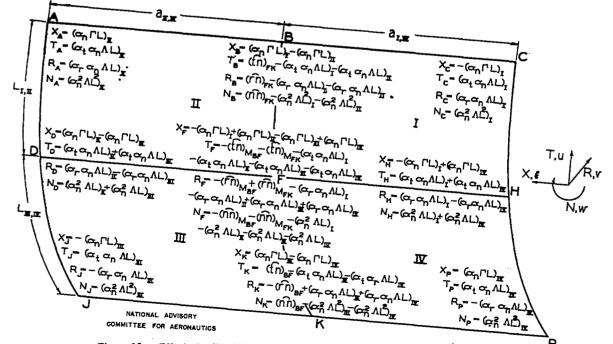


Figure 10.- Effect of unit rotation of F. Forces and moments acting on constraints. $r = \frac{Gt}{2}; \quad \Lambda = \frac{GtL}{a}. \quad \text{(Curvature opposite that in figs. 3 to 6.)}$

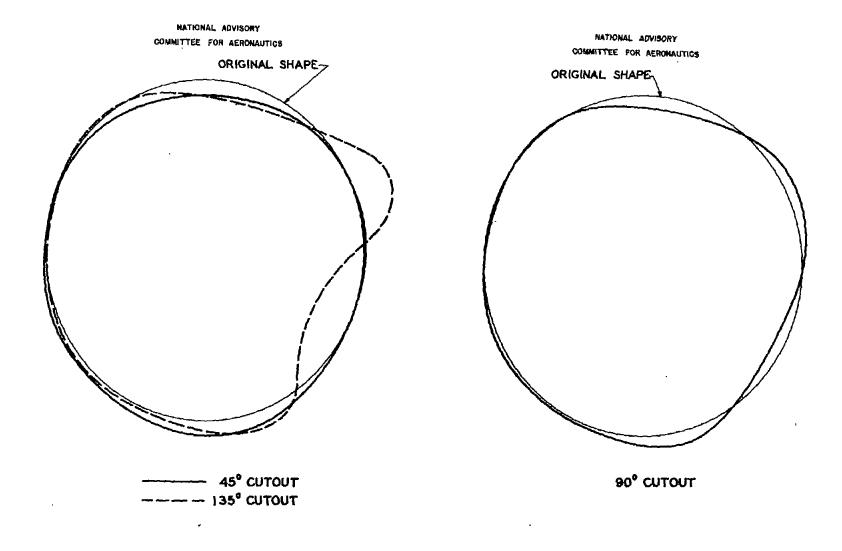
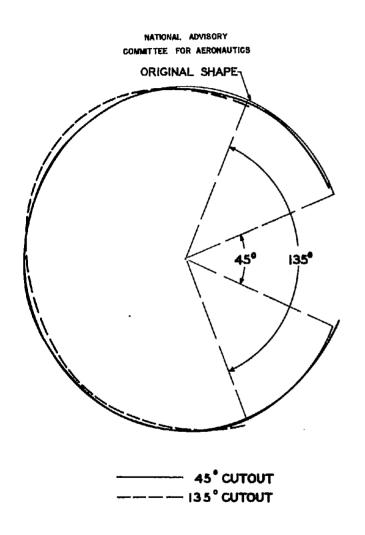


Figure 11.- Deflected shape of full rings in their own planes.

Figure 12.- Deflected shape of full ring in its own plane.



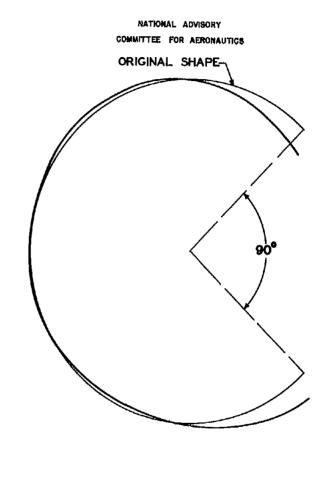


Figure 13.- Deflected shape of cut rings in their own planes.

Figure 14.- Deflected shape of cut ring in its own plane.

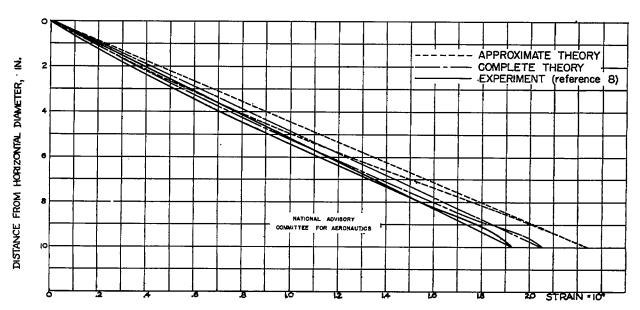


Figure 15.- Comparison of normal strain. Full section, 8 stringers, 450 cutout, M = 20,000 in-lb.

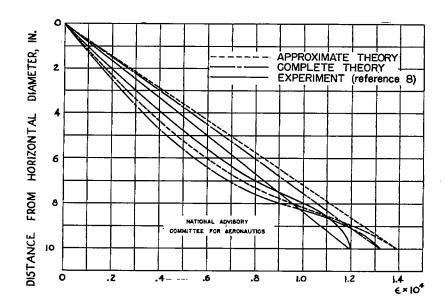


Figure 16.- Comparison of variation of normal strain. Full section, 16 stringers, 90° eutout, M=20,000 in-lb.

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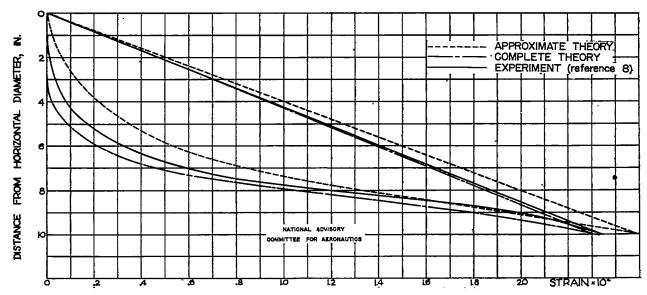


Figure 17.- Comparison of normal strain. Full section, 8 stringers, 135° cutout, M = 20,000 in-lb.

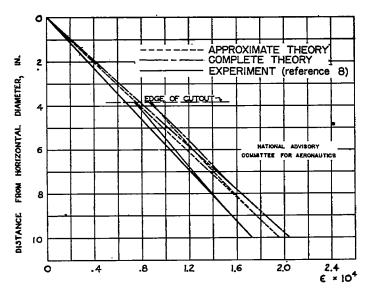


Figure 18.- Comparison of variation of normal strain. Cutout section, 8 stringers, 45° cutout, M=20,000 in-lb.

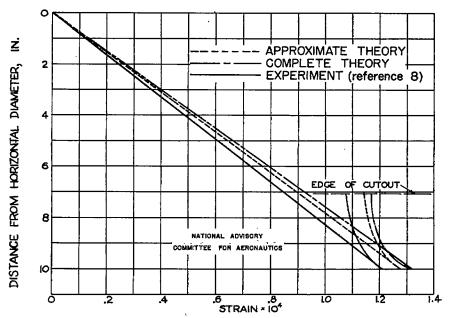


Figure 19.- Comparison of variation of normal strain. Cutout section, 16 stringers, 90° cutout, M = 20,000 in-1b.

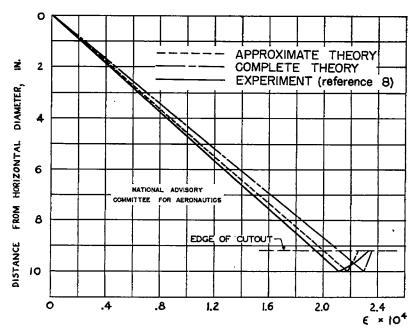
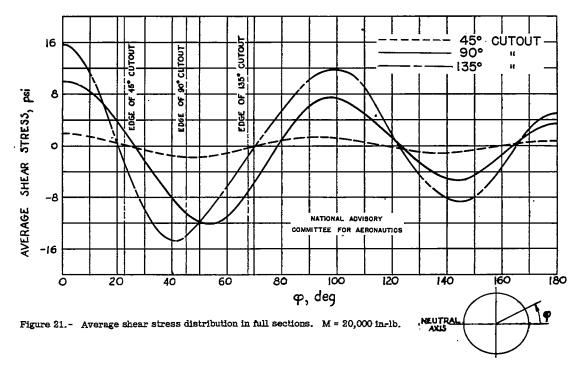


Figure 20.- Comparison of variation of normal strain. Cutout section, 8 stringers, $135^{\rm O}$ cutout, M = 20,000 in-lb.



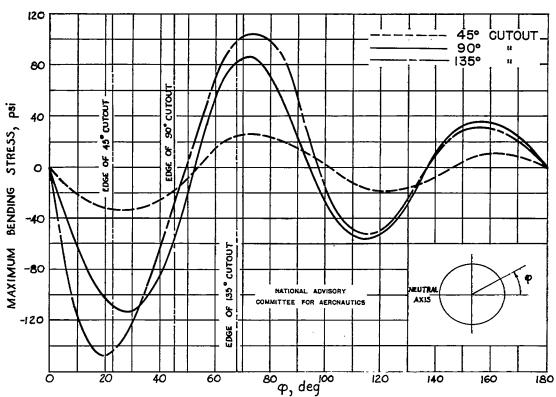


Figure 22.- Bending stress distribution in full rings. M = 20,000 in-lb.